Chapter Two

LULC CHANGES – PAST AND PRESENT STUDIES

The strong interest in land use and land cover results from their direct relationship to many of the planet's fundamental characteristics and processes, including the productivity of the land, the diversity of plant and animal species, and the biochemical and hydrological cycles. Land cover is continuously moulded and transformed by land-use changes such as, for example, when a forest is converted to pasture or cropland. Land-use change is the proximate cause of land-cover change. The underlying driving forces, however, can be traced to a host of economic, technological, institutional, cultural and demographic factors. In fact, humans are increasingly being recognized as a dominant force in global environmental change (Moran 2001, Turner 2001, Lambin et al. 2001). Changes in land use are the most ancient of all human-induced environmental impacts, and the first to obtain a magnitude to warrant the title "global." For example, land-cover change, especially the conversion of forested areas into other uses, has been identified as a contributing factor to climate change, accounting for 33 per cent of the increase in atmospheric CO2 since 1850, and a leading factor in the loss of biological diversity. Overgrazing and other agricultural practices in developing countries are causes of land degradation and desertification. Water diversion for land irrigation consumes about 70 per cent of all water withdrawals and is sufficiently significant to stop the flow of such large rivers as the Colorado (US), Huang Ho (China), and Amu Darya (Central Asia) from reaching the sea during the dry season. Human uses of land take over as much as 40 per cent of the net primary productivity of the earth, and changes in these may alter ecosystem services locally and globally (Vitousek, et al. 1997).

Against this backdrop, the United Nations (UN) Land Cover Network – an emerging cooperative activity of the UN Food and Agriculture Organization (FAO) and the UN Environment Programme (UNEP) has emerged to develop monitoring and measurement of land-cover change in support of their global environmental outlooks and assessments (e.g., the Millennium Ecosystem Assessment). In addition to these
activities, development agencies are attempting to address questions concerning the societal impacts of global change through new programs such as USAID's Geographic Information and Sustainable Development program. Such programs can help in strengthening the scientific underpinning for the decision-making process.

The changing modes of theorizing on and modelling land use change are paralleled to two broad streams of changes. First, in the conceptualization of land and land use which are affected by changes or differences in socio-cultural values, technology, economic organization, and magnitude of environmental problems associated with land use change, among others; and, second, changes in the modes of theorizing and modelling in the disciplines of the natural and the social sciences that engage in the study of land use change. Let us briefly explore some of the modelling related issues and review some of the existing studies on LULC changes.

**ASPECTS OF LULC CHANGES AND MODELLING**

Models on land use and land cover change are powerful tools that can be used to understand and analyze the important link between socio-economic processes associated with land development, agricultural activities, natural resource management strategies and the ways that these changes affect the structure and function of ecosystems. Long-term understanding of the LULC needs to propose a more dynamic framework that explicitly links what is often divided into separate "natural" and human systems into a more integrated model. In developing countries like India, it is likely that land use and land cover are often semantically equivalent, i.e. land use activities associated with logging leads to deforested land cover (Lambin, 1997). Therefore, satellite images can often be used to detect land use change through observations of the biophysical characteristics of the lands. Contrastingly, in developed countries like USA and Europe LU and LC are less likely to be equivalent. Although forestry can be modelled as a land use activity that responds to economic, social and demographic drivers (e.g. Mauldin et al. 1999, Geist et al. 2002) such drivers do not provide direct predictors for understanding and modelling the amount and locations of forests and tree cover in all parts of a landscape.

Summarizing a large number of case studies, we find that land use change is driven by a combination of the following fundamental high level causes: resource scarcity leading to an increase in the pressure of production on resources; changing opportunities created by markets; outside policy intervention; loss of adaptive capacity; and, increased vulnerability and changes in social organization, in resource access and in attitudes. Currently as many as 19 broad types of land use
change models can be identified involving spatial, temporal, and human decision-making characteristics. (Agarwal et al. 2001). These are:

i) General Ecosystem Model (GEM) (Fitz et al. 1996)

ii) Patuxent Landscape Model (PLM) (Voinov et al. 1999)

iii) CLUE Model (Conversion of Land Use and Its Effects) (Veldkamp and Fresco 1996)

iv) Area base model (Hardie and Parks 1997)

v) Univariate spatial models (Mertens and Lambin 1997)

vi) Econometric (multinomial logit) model (Chomitz et al. 1996)

vii) Spatial dynamic model (Gilruth et al. 1995)

viii) Spatial Markov model (Wood et al. 1997)

ix) CUF (California Urban Futures) (Landis et al. 1998)

x) LUCAS (Land Use Change Analysis System) (Berry et al. 1996)

xi) Simple log weights (Wear et al. 1998)

xii) Logit model (Wear et al. 1999)

xiii) Dynamic model (Swallow et al. 1997)

Towards this, a series of recent papers, reports and workshops has been carried out by members of LUCC and other research communities (Turner et al. 1995; Moran, 2000; Laurence et al. 2001; Nepstad et al. 2001, Veldkamp and Lambin, 2001; Leemans et al. 2003). Reviews that characterize and classify land use models are provided by Lambin et al. (2003) and Kaimowitz and Angelsen (1998) for deforestation, while Bockstael and Irwin (2000) gave an explanation of land use models based on economic theory. We, thus, argue that models of land use change can be linked with critical land cover outcomes (like forest cover) through the use of land cover transition models to understand land use condition and land use change. Deriving such estimates from models of LU and LUC in time and space, which are driven by exogenous variables, for the assessment of future forest cover impacts of economic, social and policy changes would be useful for land use managers and policy makers.

**STUDIES ON LULC CHANGES – BROAD SCHOOLS OF THOUGHT**

Considerable researches have been made in the areas of LULC and its changes. These studies can be broadly classified under three time divisions:

1. The Early or “Pre-industrial” period,

2. The first half of the 20th century, and

3. The second half of the 20th century.

Let us briefly describe some of them.
1. The Early Period

Among the most well known pioneers of the study of land use change are George Perkins Marsh in the U.S.A. and J.H. von Thunen in Germany. They approached the same issue from different perspectives and in different continents. The former, a prescient scholar and diplomat, examined in his seminal book *Man and Nature; or, the Earth as Modified by Human Action* (Marsh 1965; originally published in 1864) the extent and magnitude of impacts of human actions on the natural environment through the ages in various parts of the world. This study, while mainly descriptive, attempted to provide explanations of the environmental transformations observed and recorded as well as prescriptions of man’s position vis-à-vis nature. The issue of land use is central (implicitly, at least) in Marsh’s work as all human activity takes place and modifies space for particular uses. In the words of Kates et al. (1990) “The importance of *Man and Nature* lies less in the individual impacts that it catalogued than in a grouping and wide-ranging synthesis that emphasized their interrelations and traced the innumerable distant effects of human action”. The work was cited by many early conservationists and has influenced the views of nature-society relationships well beyond Marsh’s native shores. Marsh also stressed on the gravity of unintentional human impacts, and thus the need to understand the complex interactions of natural processes prior to human intervention.

Somewhat earlier than G.P. Marsh, in 1826, from the other side of the Atlantic, a North German estate owner, J.H. von Thunen, “set for himself the problem of how to determine the most efficient spatial layout of the various crops and other land uses on his estate, and in the process developed a more general model or theory of how rural land uses should be arranged around a market town. The basic principle was that each piece of land should be devoted to the use in which it would yield the highest rent” (Hoover and Giarratani 1984). Von Thunen viewed land as an economic resource whose main attribute worth considering was productivity and the landscape within which agricultural activity was taking place was flat and uniform in all directions.

The two early studies just described represent the first diametrically opposite approaches to the study of land use change. In the decades that followed, a broad variety of studies covering the whole range between these two extremes appeared but Marsh’s and von Thunen’s legacy marked the two opposing currents along which theorizing on and modelling land use change developed in the 20th century. Marsh’s comprehensive view of land, the natural environment and man’s role in causing environmental change is in the core of a host of nature-society theories and integrated models proposed in the years that followed and that are much in vogue in the present. Von Thunen’s economic, rational man producing economic goods for sale in a uniform, static and orderly landscape whose change is not a central issue
founded the theories and models of mainstream urban and regional economics in the 20th century.

2. The First Half of the 20th Century

The first decades of the 20th century saw significant changes in the uses of land brought about by industrialization and urbanization in the western world not to mention the two world wars and other major socio-economic events and technological progress. These changes were documented in studies of this period – most of which are not easily accessible, however – as well as in studies conducted in the second half of the century. They refer mostly to countries or geographic regions as well as to uses of land experiencing the most rapid and important changes such as urban areas in Europe and the USA, forests and agricultural areas in Europe, Russia, and the USA (e.g. the American Great Plains), coastal areas such as the Mediterranean basin and so on (Kates et al. 1990). The most important trait of these studies is the establishment of the systematic and "scientific" analysis of land use change based on theories and models drawn from a variety of scientific fields – mainly, economics, sociology and geography. In fact, this trait is a reflection of a broader and more general development of this period: the emergence and development of dominant modes of theorizing and modelling on land and land use in the related fields of the social sciences: urban and regional economics, urban sociology, economic and social geography.

In the economics-oriented fields, central concepts and theories appeared in this period that relate directly or indirectly to the study of land use change. In 1933, Christaller (1966) formulated the Central Place Theory to offer a theoretical account of the size and distribution of retail establishments within an urban area employing two main concepts: the "range" of a good and the "threshold" for a good. Later, Losch (1954) used the conceptual framework of Central Place Theory to offer a more general account of the patterns of "central places" in a continuous space that accounted for other urban functions in addition to retailing. Extended to the level of an urban system, Central Place Theory accounts for the size and distribution of settlements within this system. The hexagonal hierarchical patterning of places is the distinguishing characteristic of both Christaller's and Losch's (and subsequent) versions of Central Place Theory. Another concept drawing from concepts of social physics was that of human "interaction in space" (Stewart 1947, Zipf 1949) and the related notion of "accessibility" which was reflected mainly in the variability of transportation costs from some constant point in space (Haig 1927 cited in Korcelli 1982). These latter concepts provided the foundations, in the latter half of the 20th century, for the development of the spatial interaction theoretical and modelling approaches.
In the sociology-oriented fields, the development of the school of “human ecology” by sociologists of the Chicago School in the 1920s has had the greatest impact on the analysis of the land use structure and change of urban (and other) regions in this and subsequent periods (Park et al. 1925, Chorley and Haggett 1967). The principal concepts of human ecology are drawn directly from the field of ecology and they are used to describe and explain the physical patterns observed in an urban region as well as the economic and social processes underlying them. Among them, the notions of “community”, “competition”, “invasion”, “succession”, “conflict”, and “climax equilibrium” constitute central descriptive and explanatory conceptual devices. The concepts advanced to describe urban patterns, routinely mentioned in most texts of urban and regional studies and planning, are the “concentric zone” hypothesis (Park et al. 1925, Romanos 1976), the “radial sector” theory (Hoyt 1939) and the “multiple nuclei” concept (McKenzie 1933, Harris and Ullman 1945). In the same vein, the notion of “sequent occupance” was proposed to describe the geography of an area as “a succession of stages of human occupance which establishes the genetics of each stage in terms of its predecessors” (Whittlesey 1929 cited in Johnston et al. 1994). A well known application of this notion is Broek’s study of the Santa Clara Valley, California (Broek 1932).

The concepts and theories discussed above share some common characteristics that bear importantly on the analysis of land use change. Firstly, most of them are functionalist approaches to the study of urban and regional structure and change – i.e. they reflect, “An epistemological position in which teleological as distinct from causal explanatory forms are stressed” (Cooke 1983). They look for “repeatable and predictable regularities in which form and function can be assumed to be related” (Bennett and Chorley cited in Johnston et al. 1994). Second, some are predominantly descriptive (mostly the human ecology-based approaches) while some others are normative and prescriptive (Central Place Theory). Land, and space in general, does not have intrinsic properties. It is abstract and amorphous – an isotropic medium with uniform (though unspecified or highly abstract) qualities in all directions within which social and economic processes take place. Population and human activities and the uses of land associated with them are treated as though they do not extend over space but are points on a map. Even the city centre is a point – simply, the centre of a circle or a hexagon. The emphasis is on the location of human activities in space and on the form of the patterns produced – be they concentric rings or hexagonal market areas. Change in the uses of land – when it is a direct object of analysis in these frameworks – is a mechanistic and predictable response to changes in distance or transport cost, a natural consequence of the functionalism of these approaches.
3. The Second Half of the 20th Century

The scientific analysis and studies of land use change boomed after World War II along the lines of several of the approaches that had been formulated earlier. The numbers and diversity of those studies make a complete and comprehensive overview impossible. Even a simple enumeration is difficult. The studies cover the whole range from the local (urban) to the global level. The approaches adopted stem from urban and regional economics, urban and rural sociology, geography and planning as well as from the natural sciences. In addition to the mono-disciplinary, a multitude of interdisciplinary approaches have appeared especially after the 1970s. Still an overview of them can briefly be discussed.

The proliferation of studies and the particular directions pursued in the analysis of land use change are not unrelated to the broader theoretical and methodological changes in the disciplines that contributed to these studies as well as in the required supporting technology. The most important of them is perhaps the so-called "quantitative revolution" not only in geography, but also in economics, sociology and planning in the 1950s and 1960s. Formal models and theories of land use and land use change were proposed in that period to be rejected – but not abandoned – later when their limitations became evident and their foundations were questioned. The parallel progress in computer and data processing technology initially reinforced the quantitative orientation of the studies under consideration. Later on and at present, this technology appears to have an emancipating effect on the analysis of land use change in the sense that it facilitates the application of less quantitative (in the sense of the 50s and 60s), more qualitative and heuristic approaches that are not constrained by the frequently unrealistic assumptions of the earlier quantitative theoretical and modelling formulations.

Deeper changes in the perspectives of the scientific fields involved in the study of land use change at large have played, and are still playing a catalytic role in directing the analysis towards particular paths and approaches as the current (beginning of the 21st century) diversity of land use change studies testifies. Finally, the recent policy interest in the (negative) implications of global environmental change – one component of which is land use change – may be exerting an influence on the orientation of the studies of land use change as practical approaches and decision support instruments are sought to guide policy making for sustainable land use.

The systematic and scientific analysis of land use change that had started in the first half continued in the second half of the 20th century in the same fields as before – urban and regional economics, regional science, sociology, geography and planning – in several of which the related theories and models were moving to or had reached mature stages. Again, land use and its change are not always the direct object of
analysis in many fields reflecting the different focus of emphasis on particular aspects and dimensions of spatial change. However, the links to land use change are rather straightforward although not always obvious and explicitly elaborated. In addition, studies of land use change from particular fields of the natural and the applied sciences - forestry, agronomy, biology, ecology, remote sensing, environmental sciences - are not uncommon as well as studies attempting interdisciplinary approaches to the subject. Three main schools of studies are presented below. The first originates in the economics-oriented fields such as urban and regional economics and the relevant subfields of regional science, geography and urban and regional planning. The second school draws from the sociology-oriented fields like urban and rural sociology and the relevant subfields of regional science, geography and urban and regional planning. A third school contains a multifarious collection of studies originating in the same fields as before but bearing the influence of the natural sciences and opting for integrated analysis of land use change.

a. Economic Approach

The economics-oriented fields generated impressive numbers of theoretical, modelling and empirical studies of urban and regional spatial structure in the post war years. Broadly, they can be divided into those concerned with the urban and intra-urban spatial (economic) structure and those referring to larger than the regional scale areas. Most of the studies that explicitly account for land use change belong to the first group, the land-using activities more frequently analyzed being residential, commercial, transportation and, to a lesser extent, public and other services. A major stream of research is founded on neo-classical economics informed by spatial concepts; mainly the "friction of space" as measured by the distance among the location of activities. Alonso's (1964) urban land market theory and model (borrowing concepts from von Thunen's analysis) is considered the landmark study from which a series of urban economic models followed sharing a common characteristic: the description and explanation of urban spatial structure based on land rent and transportation costs and the assumption of utility maximizing individuals. For a selection of theories and models in this direction one can referred to Nijkamp (1986). In a related spirit, the 1960s saw applications of Central Place Theory to the location of retail centres, among others (Berry 1967). Another major stream of studies developed in the 1970s around the notions of spatial interaction and accessibility - already introduced in the 1940s and even earlier. It provided a theoretical framework as well as a "family of spatial interaction models" (Wilson 1974) to account for the location and allocation of activities in space taking into account the transportation network. Integrated land use-transportation models were built also to account for the simultaneity of changes in land use and accessibility.
(Putman 1983, Wegener 1986). Several variants of these models have appeared, each attempting to relax the unrealistic and introduce more plausible assumptions regarding spatial economic behaviour in space (Batten and Boyce 1986).

In a macro-economic perspective, regional equilibrium and disequilibrium theories and models, among others, developed in this period, too, to describe and explain processes of regional change (growth or decline). The theoretical and analytical framework of general equilibrium and neo-classical welfare analysis has been employed to produce Pareto optimal solutions to social welfare maximization problems where land is one of the production factors together with labour and capital (Cooke 1983, Andersson and Kuenne 1986, Clark and van Lierop 1986, Miyao 1986, Takayama and Labys 1986, Fischer et al. 1996a). Finally, empirical analyses of land use changes in urban and rural areas were conducted, responding, more or less, to pressing problems such as urban decline, rural-urban land conversion (especially on the fringe areas of metropolitan regions), urban sprawl, etc. (McDonald 1984, Simon and Sudman 1982). These have a more practical orientation focusing on detailed typologies of land uses that capture the qualitative, and not only the quantitative, intricacies of land use change (Bourne 1978).

The economics-oriented analyses of land use change share some common traits, most important of which is the emphasis placed on the price mechanism (land and transportation costs) as the principal determinant of the location of human activities in space. They are functionalist, quantitative, sometimes highly mathematical, approaches relying on frequently very restrictive assumptions with respect to the nature of land, land use, land use change as well as the characteristics and preferences of the users of space. They attempt both to describe land use patterns and their changes as well as to prescribe optimal land use configurations that satisfy set goals.

b. Sociological Approach

The sociology-oriented fields continued the tradition of human ecology developed in the first half of the 20th century producing quantitative, empirical studies of urban spatial and social structure especially in the 1960s and 1970s. Starting with the theory and technique of social area analysis and later moving to the more sophisticated inductive techniques of factorial ecology (Johnston et al. 1994), studies of land use and its change focused on such variables as socio-economic, family, and ethnic status to provide explanations for observed differences in the location of particular activities – mainly, residential areas occupied by groups of varying socio-economic traits. The characteristic of human ecological studies of this period is best summarized in Johnston et al. (1994): “Later systematizers of sociological human ecology have tended to play down the spatial focus of the Chicago School in favour of an emphasis on the demographic and institutional
dimensions of society although at the same time they have shown a strengthened interest in human interaction with the physical environment" (Johnston et al. 1994). In fact, most sociological analyses see the urban spatial structure as an expression of the underlying social structure and the associated processes (Suttles 1975, Korcelli 1982).

Within the broader realm of sociology-oriented studies of land use change, two particular approaches have developed: the behavioural and the institutional. The first attempts to describe and explain land use patterns as a function of factors influencing human behaviour and decision making and focuses on human activity systems (Chapin 1968, Chapin and Kaiser 1979, Korcelli 1982, Johnston 1982, Webber 1964a). An idealistic variation of this approach emphasizes the ways people perceive and experience the world around them and act correspondingly (Buttimer 1976 cited in Johnston 1982). The second (also called "radical" or "structuralist") places emphasis on the constraints imposed on human behaviour by societal institutions in the effort to explain spatial patterns in urban and other areas. The central concept of this approach is "power", especially economic power, and a correlate concept is 'conflict', usually between unequals, or class conflict (Johnston 1982).

These latter approaches belong to a long repertoire of approaches developed in the 1970s and beyond when geography and planning showed an interest in and were heavily influenced by social theory. Developed frequently as attacks on the empiricism and positivism characterizing most post-war descriptions and explanations of spatial structure and change, alternative approaches appeared that offered explanations of social and spatial phenomena drawing from diverse philosophical and epistemological positions. Historical materialism provided a framework within which patterns of spatial and environmental change are explained as the result of the specific social relations of the capitalist or other modes of production (Harvey 1973, 1985; for an application to land use change, see, Hecht and Cockburn 1990). Structuralist approaches sought for the truth beneath the surface of the "facts" and the "taken-for-granted" categories by means of which social life was usually comprehended (Johnston et al. 1994.). Realist perspectives oriented themselves towards the identification of the causal mechanisms underlying specific (social and spatial) structures, which occur under specific (contingent) conditions (Sayer 1982, 1985b). Giddens' "structurisation theory" sought to explore the time-space constitution of social life (see, for example, Giddens 1984). Symbolic interactionism emphasized the social construction of reality while phenomenology stressed the individuals' experiences of the world in a more or less similar fashion as existentialism which stressed the centrality of the human subject's existential being in the world (Berger and Luckmann 1967, Relph 1976, Buttimer 1974).
Ethnomethodology has taken an even more extreme stance emphasizing the unique and the idiographic and rejecting any attempt at generalizations (Jonhston et al. 1994).

A striking characteristic of all these sociology-oriented approaches which deal, in one way or another, with space, spatial structure, spatial and social relations is that they treat space and the human subjects that exist within it and interact with it in an abstract fashion; i.e. they make no explicit reference to actual land use and its changes within the context of the causal social relations studied. Moreover, frequently they lack spatial and temporal explicitness and concreteness even when they refer to the urban, regional or international level and when they deal with real world applications. In addition, several of these approaches apply to particular socio-political and cultural settings and they cannot be transferred easily and without violating their very assumptions to other contexts. Overall, in their present form and orientation, they can inform the analysis of land use change very little in practical terms.

c. Ecological and Other Approaches

Besides economics-oriented and sociology-oriented, a host of other approaches to the study of land use and its change borrowing from ideas and concepts of the past developed in the second half of the 20th century. They combine elements of both the natural and the social sciences and they are based, broadly, on the notion of ecological equilibrium which attributes changes in a region to changes in the dynamic interaction of four sets of factors: population, resources, technology and institutions (Coccossis 1991, Meyer and Turner 1996). Although not directly concerned with land use change, Ian McHarg's (1969) ecological method for land use and landscape planning is worth noting here. On one hand, it bears the influence of past streams of thought on the man-environment relationship and, on the other, it has marked, in its turn, the way of thinking about the relationship between human activities and nature and of planning for their harmonious symbiosis. The ecological method he had advocated was an appeal to consider the life processes as constraints and opportunities for land use planning. His was a holistic approach as the following statement reveals: "The social value of a given environment is an amalgam of the place, the people, and their technology. People in a given place with opportunities afforded by the environment for practicing a means of production, will develop characteristic perceptions and institutions. These institutions will have perceptions and values that feed back to an understanding of the environment ... and that have a modification of technology" (McHarg 1979).

Ecosystem-based theoretical approaches and integrated environment-economy-society models became widespread in the last half of the 20th century and especially after the 1970s. The broader climate of this period is marked by the growing
appreciation of and concern about the environment in policy and academic circles as well as and among laypersons which created a demand for approaches and tools of analysis of the related problems. Land use and its changes came to be recognized as important elements of the broader nature-society system and non-trivial contributors to global environmental change whose study was a prerequisite for taking action (see, for example, Slocombe 1993, Lutz 1994, Fischer et al. 1996a, Manning 1988, 1991). What distinguishes these approaches from the previous two groups is the treatment of land and land use as having intrinsic and variable environmental (and not only economic and socio-cultural) properties, attributes and capabilities that influence and are influenced by human activities and actions. Hence, land use change is analyzed within a meaningful setting of nature-society interactions which appears to be more promising in handling policy and decision making issues in an integrated manner than the more uni-dimensional approaches discussed before which focus on only one dimension of the subject.

**RECENT DEVELOPMENTS AND EMPIRICAL STUDIES**

In addition to theoretical and methodological studies, a host of empirical studies have been and are undertaken at both the international and lower levels to identify and record changes in major uses of land, mostly when and where these changes have grave ecological (and economic) consequences as in agricultural, forest, and urban areas. Turner et al. (1990) and Meyer and Turner (1994) provide historical accounts of global studies and present the current trends in this perspective. Besides global level assessments of land use changes, land use change research in individual countries has provided stock taking of major land use changes on a variety of spatial scales as input to both research and policy activities (see, for example, Brouwer 1991, Jongman 1995, CLAUDE 1996). Technological progress in the domain of (spatial) data management and remote sensing has spurred major projects on observing and recording land use changes. Powerful earth observation systems covering the globe (e.g. those utilized in programs such as GCOS, GCTE, GOOS, GTOS, LANES, TREES to name but a few) together with advanced spatial data management systems (Geographical Information Systems) offer the possibility to monitor and map land cover changes at very disaggregate levels of spatial and temporal resolution. In addition, they facilitate data storing and processing for use in various contexts such as in scientific research, policy making, and implementation of related programs (Liverman et al. 1998).

In the last decade of the second millennium, the 1990s, the study of land use change could be no exception to the sustainable development movement. An almost universal concern with global environmental change had already gained ground also
and had spurred a large number of research and policy initiatives around the globe especially after the Rio Summit of 1992. Examples include the research initiatives of IGBP, IHDP, the FAO, the European Environment Agency (EEA) as well as the UN Conventions on Climate Change (UNCCC), Desertification (UNCCD), and so on. Land use change was soon recognized as a significant component of the global environmental system as “the lands of the earth bear the most visible, if not necessarily the most profound, imprints of humankind’s actions” (Kates et al. 1990) and specific research initiatives, such as LUCC, were formed. At the same time, the scientific fields contributing to the analysis of land use change had matured more or less in terms of theories, models and tools (technology). Interdisciplinary research was undertaken both within broad scientific realms (e.g. the environmental sciences) as well as between scientific realms on the society-environment interface as it was beyond question that the answers to almost all environmental and social problems could not be provided within the narrow confines of any discipline.

As a result of these developments, among many others, the outlook on the subject has broadened and the approaches advanced are more holistic than they were in the past. Despite the persistence and inertia of strong disciplinary boundaries, new forms of scientific cooperation are promoted under the call for “transdisciplinarity”. A return to the view of land as a multi-faceted resource and of land use as the wise manipulation and stewardship of this resource is encouragingly visible, echoing the legacy of the past, although it cannot be claimed that it is the dominant view yet.

Studies of land use change cover the whole spectrum from the global to the local. But, in most cases, studies at particular spatial levels are usually conducted in isolation from one another and, frequently, they fall within the purview of particular disciplines (e.g. urban economics, geography, environmental sciences, forestry, etc.). This kind of scientific segregation inhibits the exchange of concepts, theories, tools, and results among spatial levels. Global level land use change studies have received greater publicity compared to the other levels given the stronger interest, in general, in global environmental change and the requirements of global policies such as UNCCC and UNCCD. It is recognized, however, that many of the global impacts of land use change result mostly from the many incremental local level decisions and actions of the actual users of land. Hence, the heightened recent interest on integration – among spatial scales, of local with regional and global level analyses, of urban with rural analyses etc. Integrated analysis is a relatively under-researched area in most disciplines given, among others, the problems with integrating/synthesizing theoretical and methodological frames of analysis from different disciplines as well as the more mundane but hoary “data problem”. Judging from the LUCC Implementation Strategy (LUCC 1999), however, it seems that future
studies of land use change will be increasingly characterized by integrated, interdisciplinary approaches to address the issues associated with the management of land use change. This task is expected to be facilitated greatly by further advances in the systems of data collection, compilation and management assuming that the currently high costs and long times associated with the provision of the required data will be reduced to reasonable levels.

**LAND USE / LAND COVER ANALYSIS – THE INDIAN EXPERIENCE**

4. Existing Studies

From initial knowledge on extrinsic and intrinsic factors operating at different spatial and temporal scales an alarm needs to be developed for quantifying LULC changes in developing countries in general and in India in particular. In the past few decades there has been change in land use, because of expansion of agriculture & mining areas, increment in construction of dams, industrialization, urbanization, etc. to name a few, which affect LULC as external factors. Internal changes include shifting cultivation areas, selective logging due to human pressure on forest resources and habitat loss of wildlife due to reduction in forests. Studies so far conducted in India on LULC change are scattered, particularly in regions like Western and Eastern Ghats, the Himalayas and North-eastern states. In Western Ghats over the past centuries the changes in landscape are mainly owing to plantations (tea, coffee, rubber, teak, etc.) and some to anthropogenic pressure.

Menon and Bawa (1998) have estimated the rate of deforestation in the Western Ghats to be 0.57 per cent annually during the period 1920–1990 and Prasad et al. (1998) have assessed 0.90 per cent annual decline in natural forest cover in Kerala for the period 1961–1988. Deforestation has been particularly intensive in the southern Western Ghats, which lost a quarter of its forest cover between 1973 and 1995 (Jha et al. 2000). The data from the Agastyamalai region, Western Ghats, indicates a five-fold increase in forest loss from the periods 1920–1960 and 1960–1990 (Ramesh et al 1997).

Arunachal Pradesh over the past decades has not only resulted in the large-scale loss of forest cover, but has also caused the land cover change, fragmentation of the remaining habitat into numerous isolated patches (Ramesh et al. 1997; Menon and Bawa, 1998; Prasad et al. 1998; Jha et al. 2000; Menon et al. 2001).

Attempt to model vegetation and land cover particularly in Indian region e.g. forest cover change at landscape scale (Menon et al. 2001; Giriraj, 2005), as a direct function of socio-economic changes, land use patterns with bio-geophysical characteristics to predict areas most susceptible to future deforestation and biodiversity loss.
Recently, IIRS and NRSA prepared vegetation and land cover mapping for entire Western Ghats of India on 1:25 000 scale using IRS LISS III satellite data (IIRS, 2002) to identify major areas of fragmentation, disturbance and biological rich areas.

5. Proposed land use/land cover inventory under NR census

As the land use/cover maps statistics generated were evaluated by the Planning Commission, Ministry of Rural Development, Department of Science and Technology of Government of India etc. a need for large scale nationwide land use/land cover analysis on a five-year cycle was felt as part of “Natural Resources Data Infrastructure”. Under this it is proposed to bring out a “Status of NR Census” report at national level every five years considering 2000 to 2001 as the base year, which covers the land use/cover information or other important theme. It will address the issues concerning irrigated and rainfed areas, current fallows, forest types and canopy density information at various administrative levels, human settlement areas and their dimensional changes with respect to urban, town and rural settlements. The periodic data on changes of water bodies serve as an indicator for the drought prevalence in parts of the country. The dynamics of waterlogged/wetlands information serve as vital environmental parameters.

In the above context, spatially and temporally explicit monitoring and evaluation assume greater importance. The national spatial databases to enable the monitoring of temporal dynamics of agricultural ecosystems’ increase in mining, industrialization and urbanization, forest conversions, surface water losses are lacking. These kinds of databases are of primary importance for national accounting of natural resources and planning at regular intervals.

OBJECTIVES OF THE PRESENT STUDY

As is evident from the above discussion of existing literature, LULC changes have become a crucial area of study in the last fifty years. While developed countries are doing lots of research on this and related issues, there is a dearth of such studies in developing countries, especially India. The small numbers of studies in India have been concerned mainly with the mountainous and hilly regions – the Eastern and Western Ghats and the Himalayan Region where natural land cover changes have altered worldwide attention. However, the magnitude and impact of LULC changes are far more substantial and far-reaching in countries in areas where the pace of development have necessitated considerable changes in the natural environment, for example, in the river basins. This calls in for detailed micro-level study of such regions so that the impacts can be studied and policies for mitigating future catastrophes can be suggested. This has been the main motivation for the present study.
Our study area – the Lower Damodar basin – is the region where the river Damodar has started bifurcation and formed deltaic characteristics. The region is falling directly under the command area of DVC. Irrigation water is provided throughout the year. As a result the area is experiencing fast rate of growth in the extension of the agricultural lands.

On the other hand, the region is located in the midway between the heavy industrial zones (Ruhr of Bengal) in the west and the great cosmopolitan consumer market of Kolkata in the east. The flow of industrial products or the consumers take a break in the Burdwan town. The town still bears the characteristics of duality of rural and urban character. The people of both the industrial region and of Kolkata want to get settled in Burdwan town. The resultant effect of these cultural phenomena is fast rate of expansion of the settlement area in the police station. Keeping this view in mind, we have tried to examine the historical change in land use / land cover of the Damodar deltaic region (along with case studies of Burdwan and Bhatar police station within the region).

The basic objectives of the present study are as follows:

1) To examine the pattern and magnitude of changes in LULC in the flood plain;
2) To identify the spatial covariates associated with those changes;
3) To examine the historical nature and trend of reclamation of natural lands within the bed of the river Damodar;
4) To explore how this process is reinforced through socio-economic activities;
5) To explore how LULC changes are affecting Water availability in the region as it is the most important requirement of modern society;
6) To forecast likely consequences of such changes using Markov Dynamic Spatial Model and Markov Random Chain;
7) To suggest policies for avoiding harmful effects of such changes.

DVC is acronym for the Damodar Valley Corporation, an autonomous River Valley Planning Body set up in 1949 for administration of the River Damodar in India, especially for controlling the multipurpose Dams and Barrages on the river and the associated Irrigation and Power generation networks.